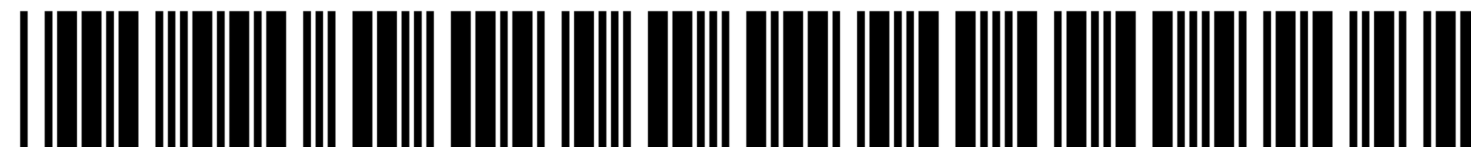
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Shiue et al.

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(45) **Date of Patent: Nov. 1, 2011**

(54) **LIGHT EMITTING DIODE DEVICES AND MANUFACTURING METHOD THEREOF**

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(22) Filed: **Feb. 7, 2008**

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(30) **Foreign Application Priority Data**

Jul. 10, 2007 (TW) .... 96125039 A

(51) **Int. Cl.**
H01L 21/00 (2006.01)

(52) **U.S. Cl.** **438/28**; 438/458; 438/459; 438/46; 257/E21.599; 257/E33.001

(58) **Field of Classification Search** 438/34–35, 438/39–40, 460–465, 29, 42–43, 26, 28, 438/33, 38, 98, 99, 88, 91, 458, 459, 670; 257/E21.6–E21.61, E33.068, E33.075, E33.06, 257/E33.072–E33.073, E21.699, E21.7, E21.599, 257/E21.51, E25.021, E33.067, E21.697, 257/E21.54, E33.055, E33.056, E33.062, 257/E33.001
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,423,560	B1 *	7/2002	Trezza et al.	438/25
6,806,112	B1 *	10/2004	Horng et al.	438/29
6,876,005	B2	4/2005	Hsieh et al.	
6,884,646	B1 *	4/2005	Wu et al.	438/22
6,969,626	B2	11/2005	Guo et al.	
7,026,181	B2	4/2006	Guo et al.	
7,473,571	B2 *	1/2009	Hwang et al.	438/46
7,488,613	B2 *	2/2009	Kunisato et al.	438/47
7,563,629	B2 *	7/2009	Lee et al.	438/34
7,572,652	B2 *	8/2009	Ikemoto et al.	438/22
7,588,952	B2 *	9/2009	Lee et al.	438/28
7,867,795	B2 *	1/2011	Shiue et al.	438/28
2002/0055237	A1 *	5/2002	Sayyah	438/458
2004/0079951	A1 *	4/2004	Horng et al.	257/79
2006/0246687	A1 *	11/2006	Kaiser et al.	438/458
2008/0283503	A1 *	11/2008	Liu et al.	216/99
2008/0315220	A1 *	12/2008	Lee et al.	257/94
2010/0159622	A1 *	6/2010	Hsieh et al.	438/29

FOREIGN PATENT DOCUMENTS

TW	I224876	12/1992
TW	0543210 B	7/2003

* cited by examiner

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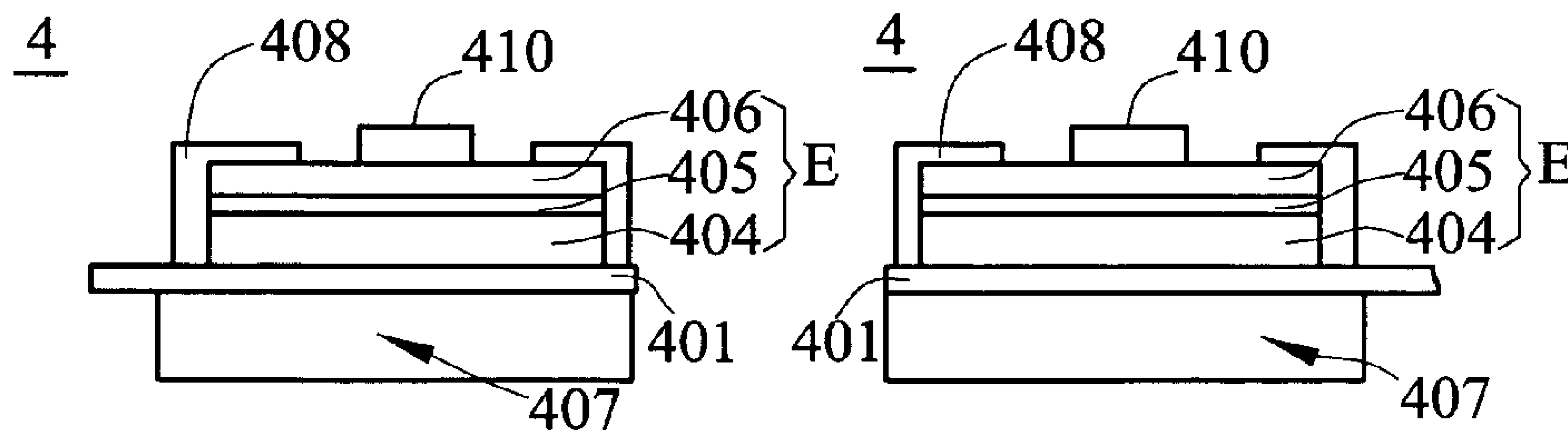
(57) **ABSTRACT**

A light emitting diode (LED) device includes a stacked epitaxial structure, a heat-conductive plate and a seed layer. The stacked epitaxial structure sequentially includes a first semiconductor layer (N—GaN), a light emitting layer, and a second semiconductor layer (P—GaN). The heat-conductive plate is disposed on the first semiconductor layer, and the seed layer is disposed between the first semiconductor layer and the heat-conductive plate. Also, the present invention discloses a manufacturing method thereof including the steps of: forming at least one temporary substrate, which is made by a curable polymer material, on an LED device, and forming at least a heat-conductive plate on the LED device.

15 Claims, 5 Drawing Sheets



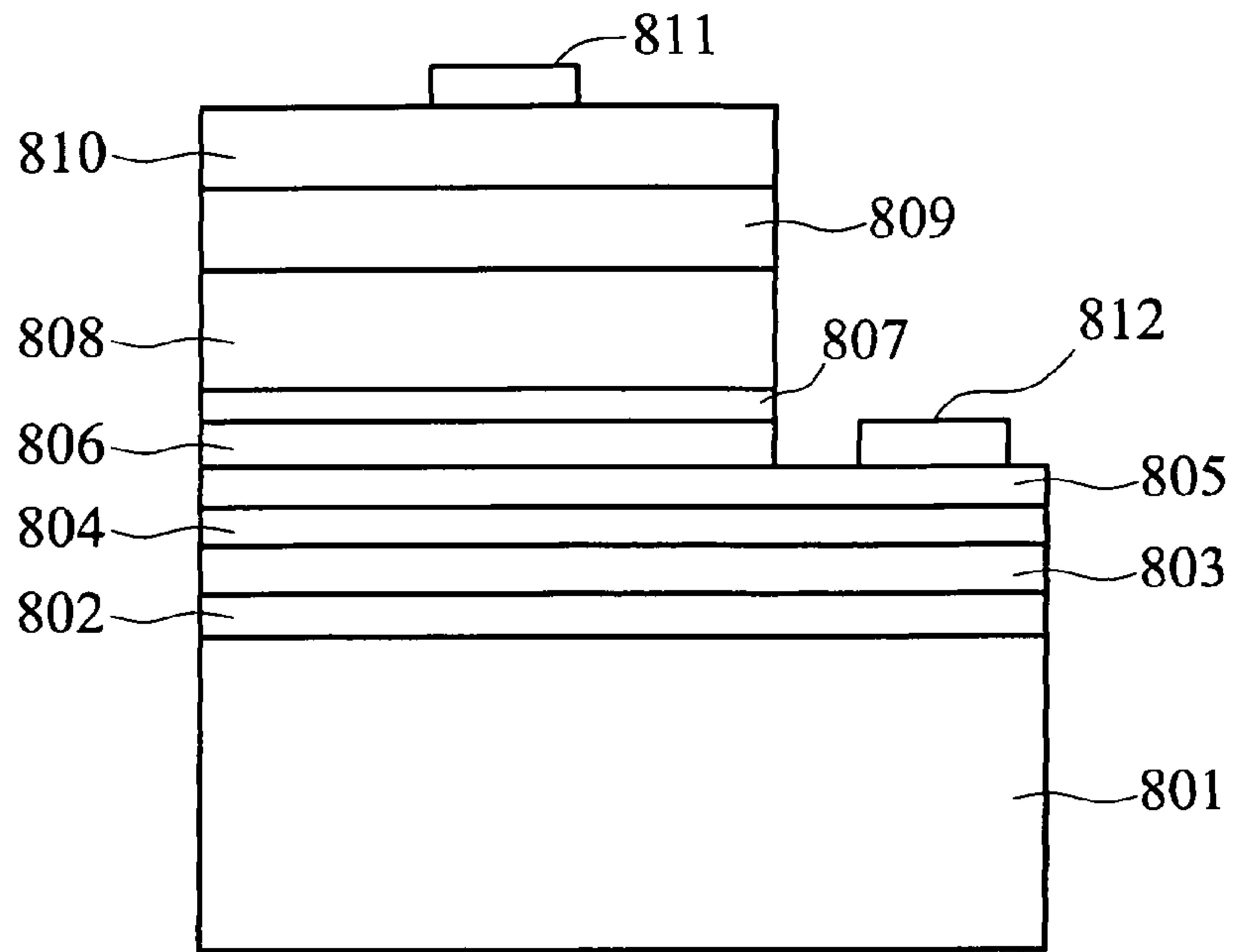


FIG. 1 (PRIOR ART)

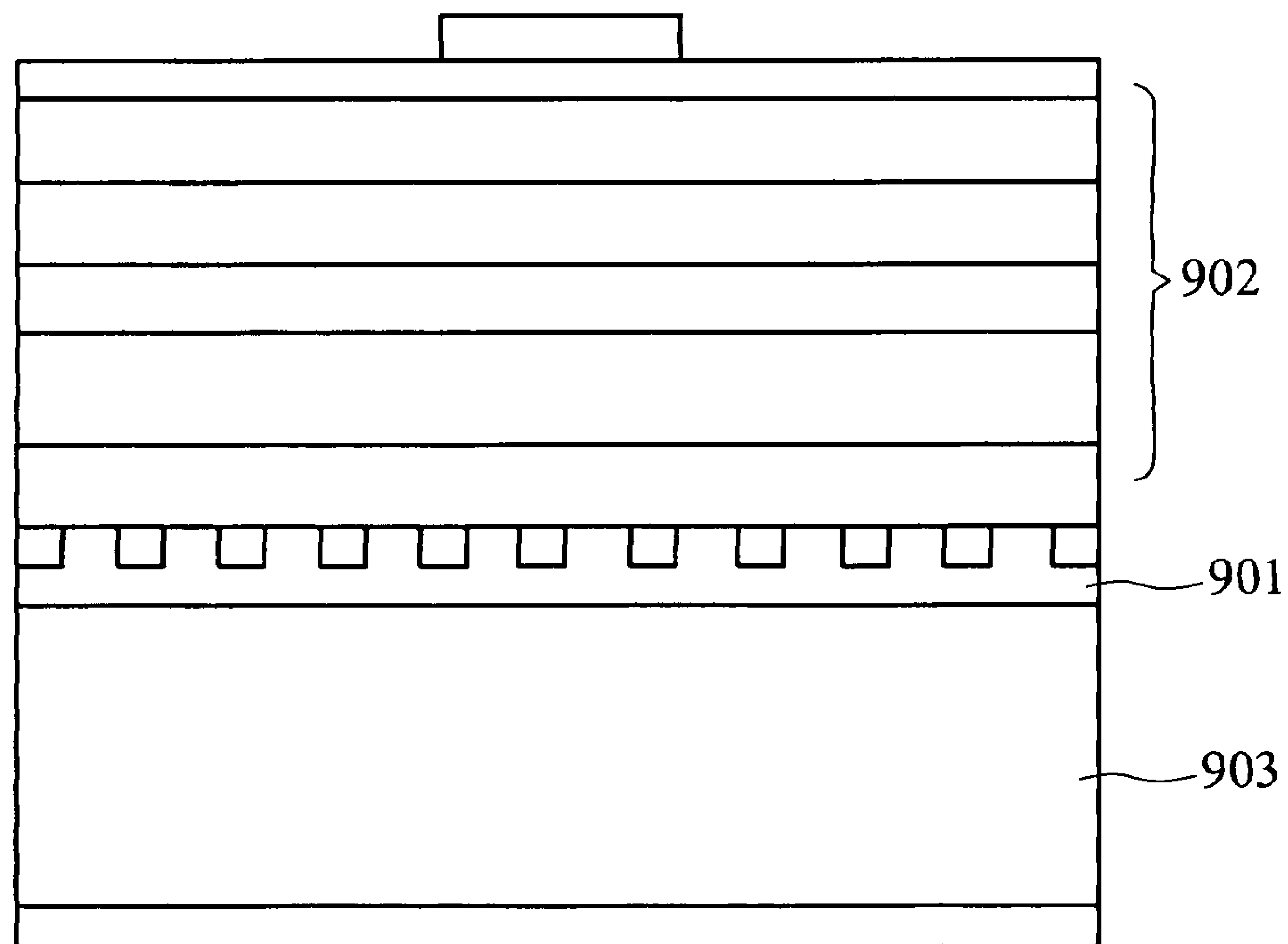


FIG. 2 (PRIOR ART)

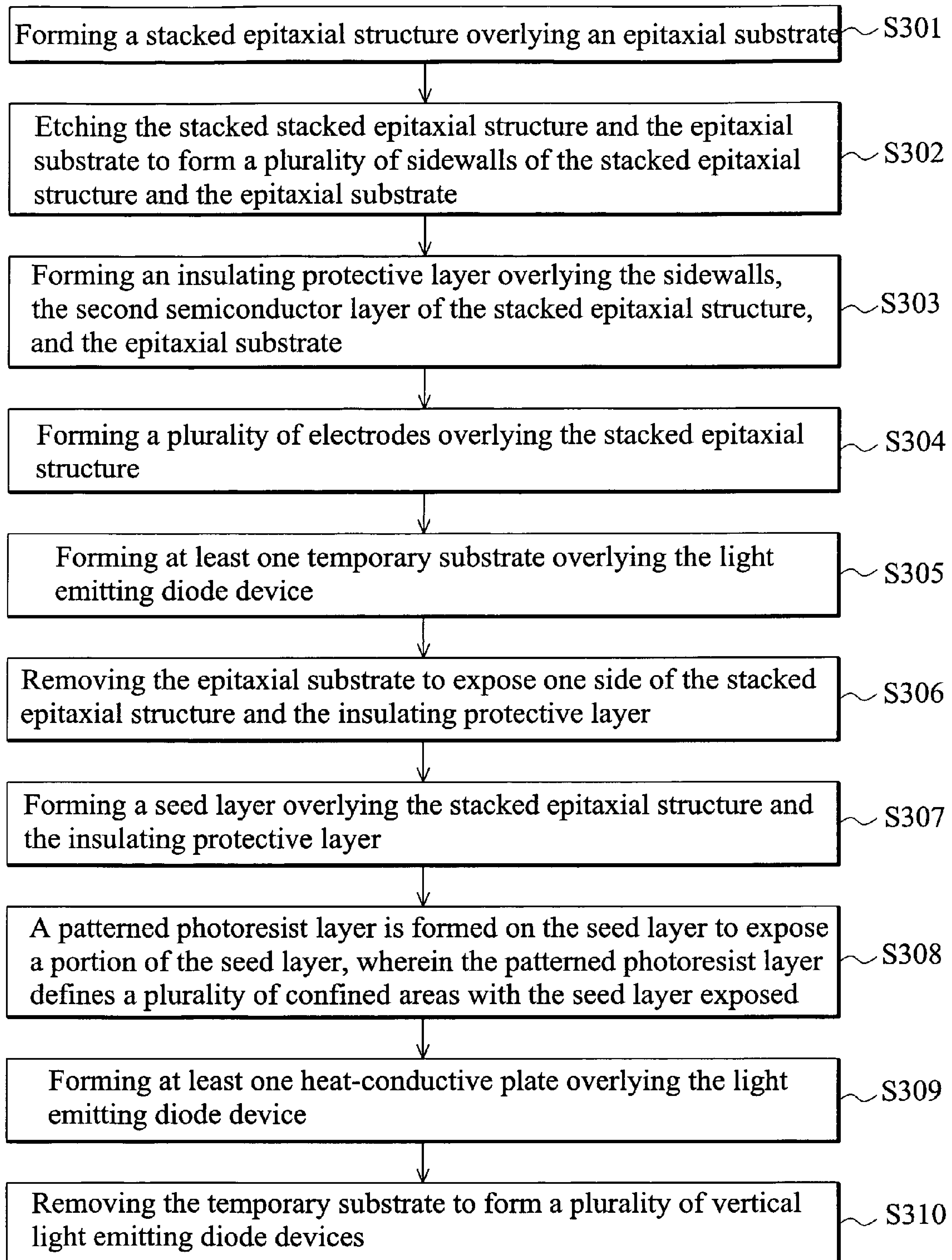


FIG. 3

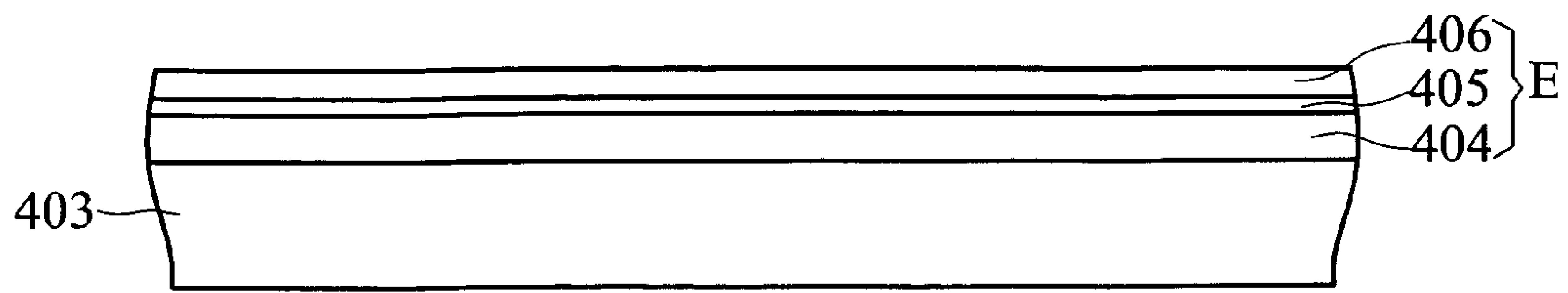


FIG. 4A

FIG. 4B

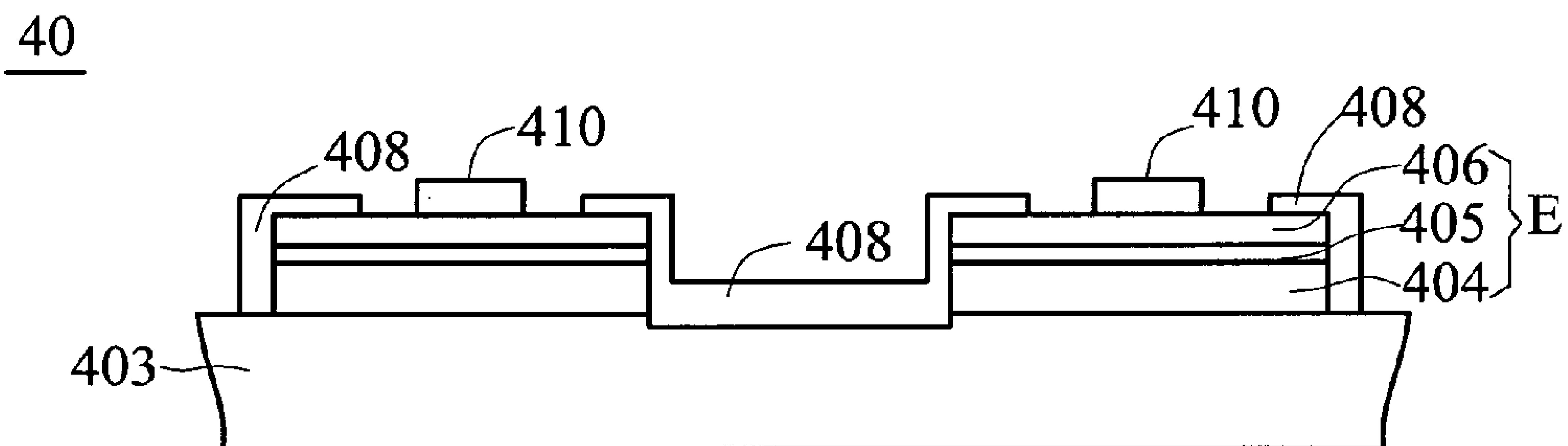


FIG. 4C

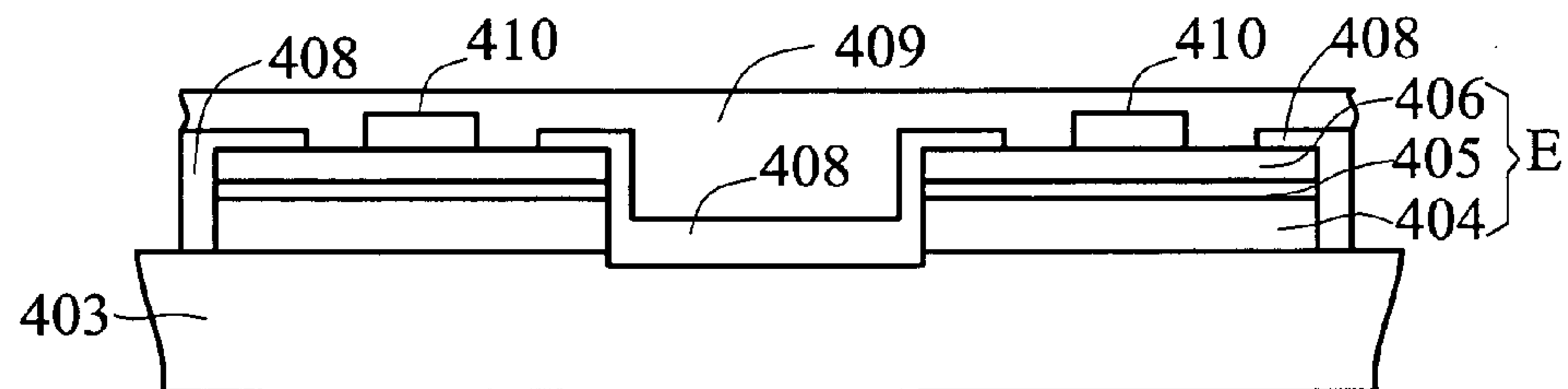


FIG. 4D

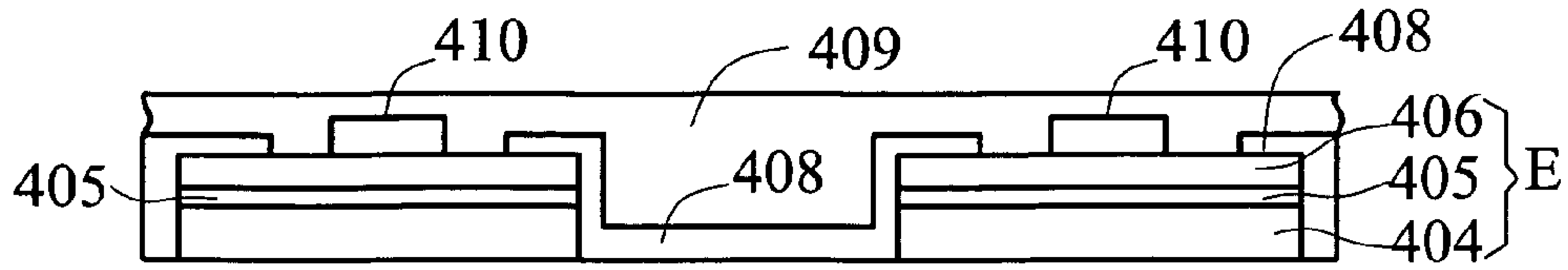


FIG. 4E

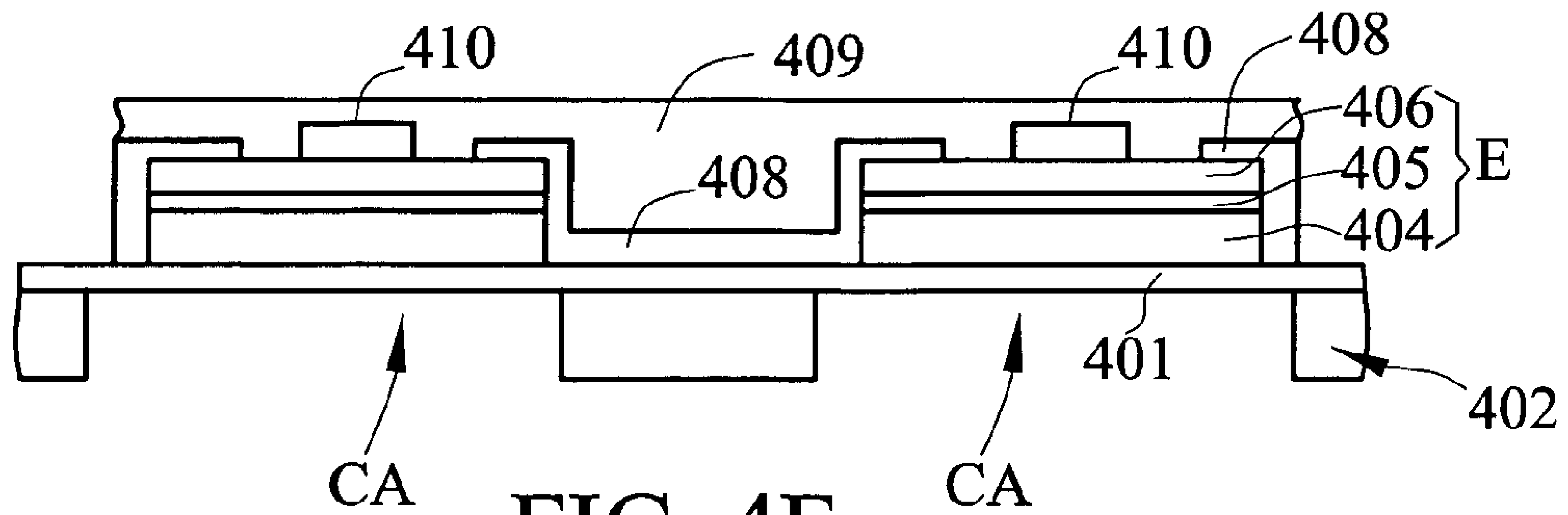


FIG. 4F

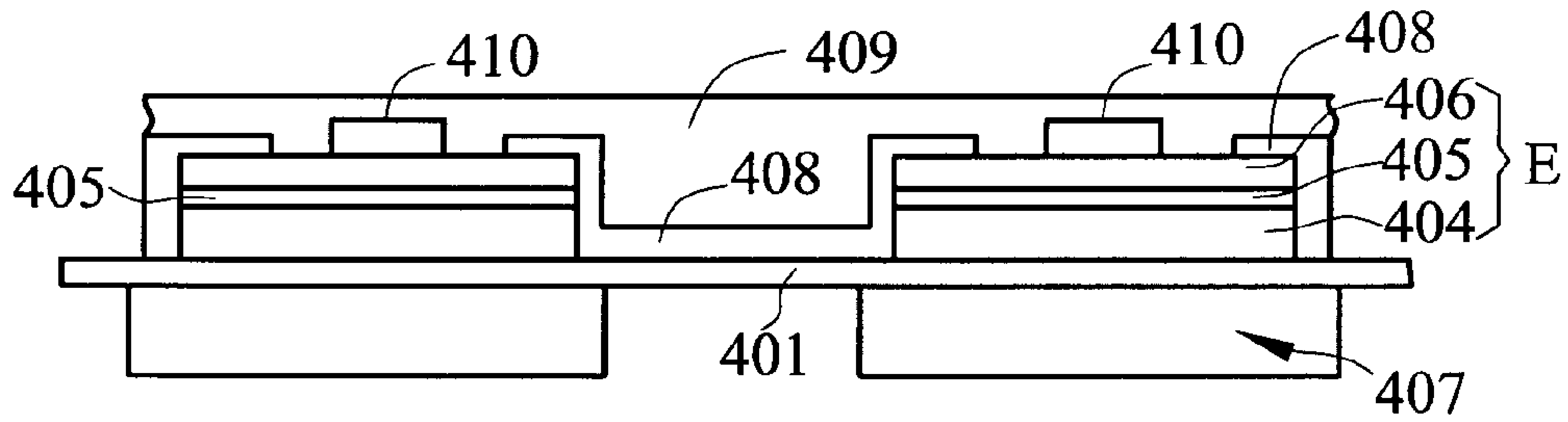


FIG. 4G

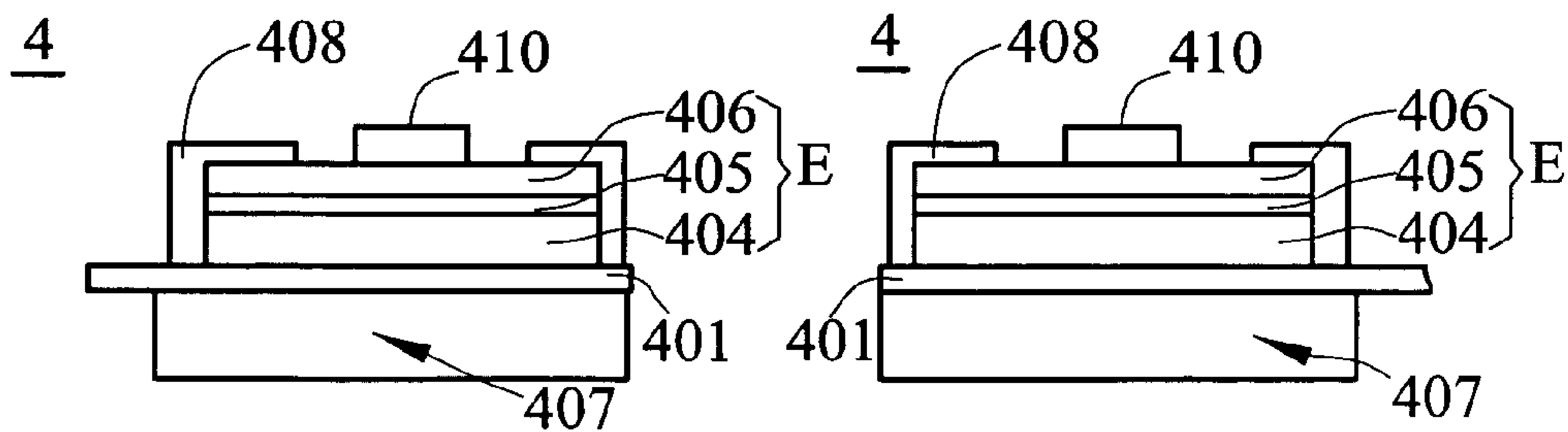


FIG. 4H

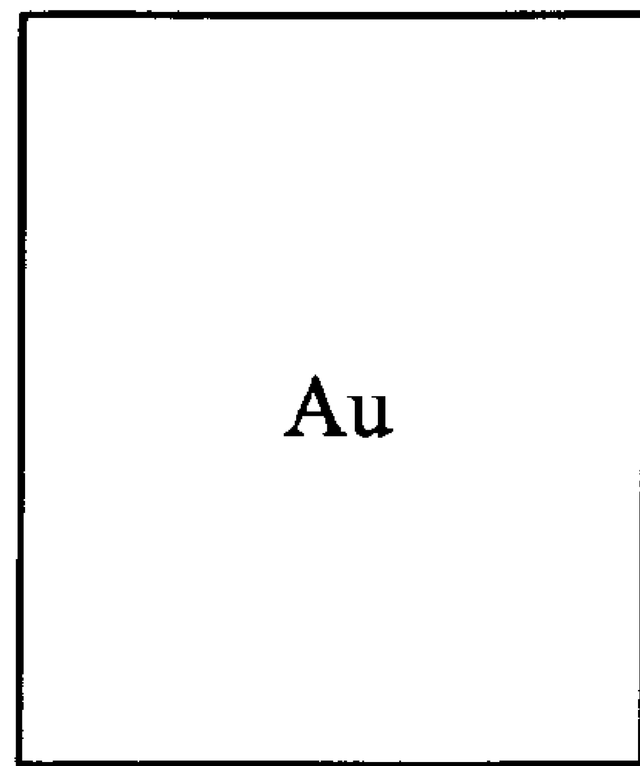


FIG. 5A

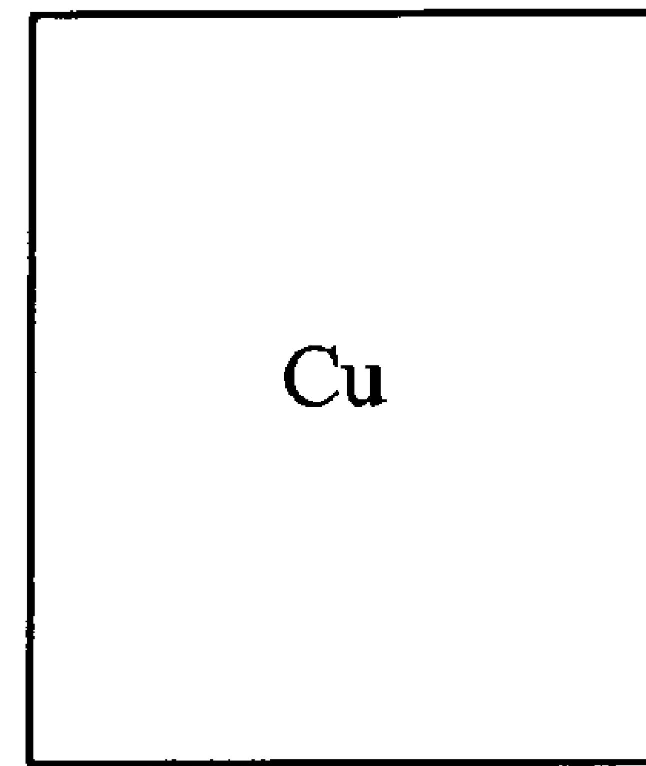


FIG. 5B

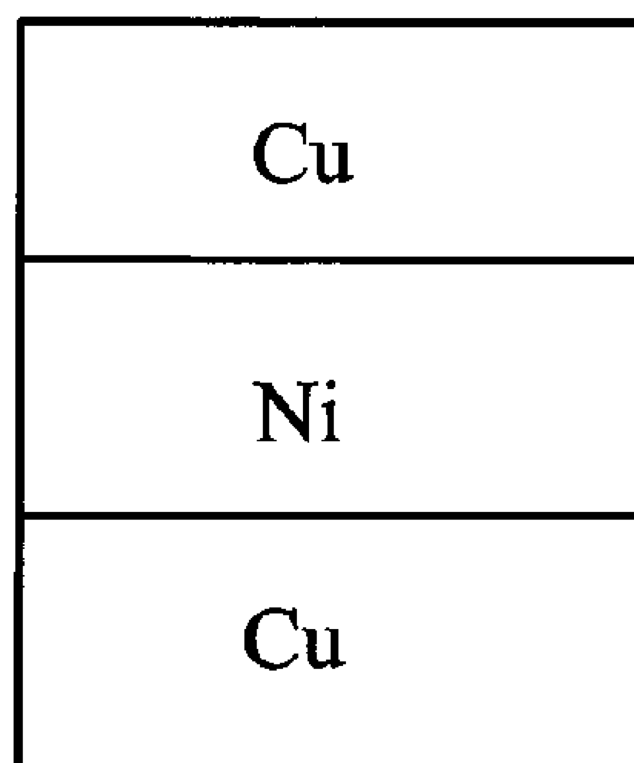


FIG. 5C

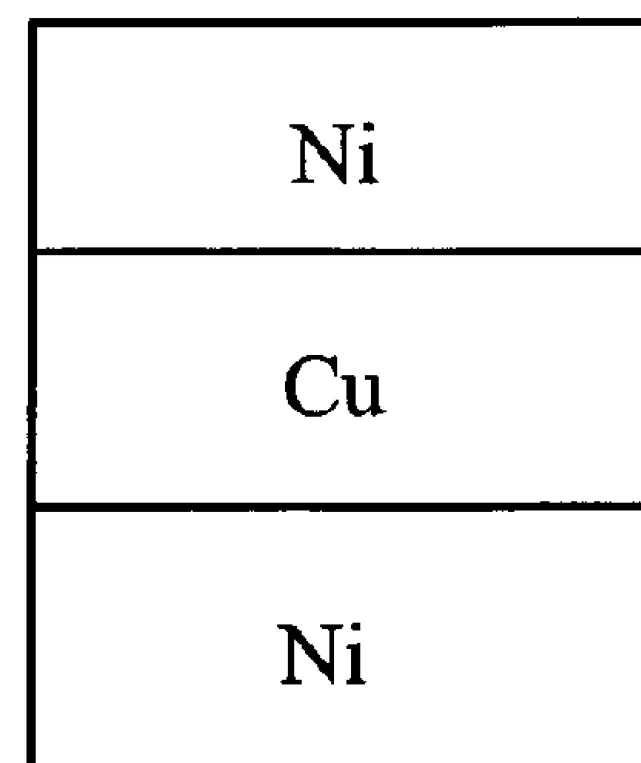


FIG. 5D

LIGHT EMITTING DIODE DEVICES AND MANUFACTURING METHOD THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a light emitting diode device and a manufacturing method thereof.

2. Description of the Related Art

A light emitting diode (LED) device is a semiconductor luminescent device, providing many advantageous features such as low power consumption, long lifetime, short response time, and so on. The sizes of LED devices are so small that they are easily manufactured to very small devices. Thus, with the continuous improvement of the technology recently, applications of LED devices have been applied in indicator lights of computers or home appliances, back light units of liquid crystal display device, traffic signals, or indicator lights of cars.

According to the prior art, in order to improve luminescence efficiency of LED devices, metal reflective substrates are disposed on LED devices reflecting light to improve luminescence efficiency. However, there are some problems with such LED devices which need to be solved.

FIG. **1** shows the LED device disclosed in Taiwan Patent No. 0544958. The LED device includes a metal reflective substrate **801** and a stacked structure on the metal reflective substrate **801**. The stacked structure sequentially includes a first reaction layer **802**, a transparent bonding layer **803**, a second reaction layer **804**, a transparent conductive layer **805**, a first contact layer **806**, a p-type epitaxial layer **807**, a light emitting layer **808**, an n-type epitaxial layer **809**, and a second contact layer **810**. In addition, an electrode **811** and an electrode **812** are disposed on the second contact layer **810** and the transparent conductive layer **805**, respectively.

The LED device is formed by bonding the first reaction layer **802** with the second reaction layer **804** through the transparent bonding layer **803** and bonding the metal reflective substrate **801** with the first reaction layer **802**. However, since the transparent bonding layer **803** is made of plastic materials, the heat generated from the LED device can not transfer to the metal reflective substrate **801** and dissipate effectively. As a result, the efficiency of the LED device dramatically decreases when the heat inside the LED device continuously accumulates.

Additionally, in the dicing process, a plurality of LED devices are obtained by dicing the metal reflective substrate **801** and the stacked structure. However, the metal particle produced in the dicing process can adhere to the sidewalls of the stacked structure and thus increase the leakage current of the stacked structure.

FIG. **2** shows the LED device disclosed in Taiwan Patent No. 0543210. The LED device is formed by bonding a light emitting diode stacked structure **902** with a metal reflective substrate **903** through a metal bonding layer **901**. The bonding of the metal bonding layer **901** with the metal reflective substrate **903** requires a high temperature and high pressure, which, however causes inter-diffusion between the light emitting diode stacked structure **902** and the metal reflective substrate **903**. In addition, the leakage current of the light emitting diode stacked structure **902** can increase due to the dicing process.

The two conventional LED devices above are both fabricated by forming the stacked epitaxial structure on an epitaxial substrate, then disposing the stacked epitaxial structure on a glass substrate or an electroplating substrate through a replacement process, and then dicing into individual LED devices. Thus, while an additional dicing process is needed for the method described, the probability of metal particles adhering to the sidewalls of the stacked structure is high.

BRIEF SUMMARY OF INVENTION

An object of the invention is to provide an LED device having an electric forged heat-conductive plate with low residual stress and heat corrosion resistance. The LED device can be formed without any dicing process, thus allowing costs and the leakage current to be reduced.

Thus, to achieve the above objective, the invention provides a light emitting diode device including a stacked epitaxial structure, a heat-conductive plate, and a seed layer. The stacked epitaxial structure includes a first semiconductor layer, a light emitting layer, and a second semiconductor layer. The heat-conductive plate is disposed with respect to the first semiconductor layer and the seed layer is disposed between the first semiconductor layer and the heat-conductive plate. Therein, the first semiconductor layer is an n-type epitaxial layer and the second semiconductor layer is a p-type epitaxial layer. For example, the first semiconductor layer is an N—GaN layer and the second semiconductor layer is a P—GaN layer.

The invention further provides a method for manufacturing a light emitting diode device, wherein the method includes: forming at least a temporary substrate on a light emitting diode device, and forming at least a heat-conductive plate on the light emitting diode device.

Therein, the temporary substrate is a curable polymer material. Because the finished LED device can be obtained by removing the temporary substrate after removing the epitaxial substrate by etching or laser ablation, dicing is not required and the probability of the metal particle adhering to the sidewalls of the stacked epitaxial structure can be reduced. In addition, the heat-conductive plate of the invention has low residual stress and heat corrosion resistance which can prevent the separation between the stacked epitaxial structure and the heat-conductive plate or the damage of the stacked epitaxial structure. The advantageous features of the invention include that product yield can be improved and costs can be reduced.

As mentioned above, the method for manufacturing a light emitting diode device according to the invention is featured by forming a temporary substrate on a light emitting diode device, and forming at least a heat-conductive plate on the light emitting diode device. Compared with prior art methods, the invention takes advantage of the characteristics of curable polymer material such as its removability, expandability, and ductility to separate the devices naturally to form a plurality of LED devices after easily removing the temporary substrate. Thus, the problem of leakage current generated from the dicing process can be prevented and thus reduce the costs of the dicing process and improve product yield.

BRIEF DESCRIPTION OF DRAWINGS

The invention can be more fully understood by reading the subsequent detailed description and examples with references made to the accompanying drawings, wherein:

FIG. **1** is a cross-sectional view of a conventional LED device;

FIG. **2** is a cross-sectional view of another conventional LED device;

FIG. **3** is a flow chart showing the manufacturing steps of the LED device according to a preferred embodiment of the invention;

FIG. **4**A to FIG. **4**H are cross-sectional views showing the steps for fabricating LED devices according to the preferred embodiment of the invention; and

FIG. **5**A to FIG. **5**D are cross-sectional views of various heat-conductive plates shown in FIG. **4**H.

DETAILED DESCRIPTION OF INVENTION

The following description is of the best-contemplated mode of carrying out the invention. This description is made for the purpose of illustrating the general principles of the invention and should not be taken in a limiting sense. The scope of the invention is best determined by reference to the appended claims.

FIG. **3** is a flow chart showing the manufacturing steps of the LED device according to a preferred embodiment of the invention, wherein the flow chart includes step S**301** to step S**310**. Hereinafter, please also refer to FIG. **4**A to FIG. **4**H.

As shown in FIG. **4**A, a stacked epitaxial structure on an epitaxial substrate **403** is formed, wherein the stacked epitaxial structure E sequentially includes a first semiconductor layer **404**, a light emitting layer **405**, and a second semiconductor layer **406** (step S**301**). The first semiconductor layer **404** is formed on the epitaxial substrate **403**, then the light emitting layer **405** is formed on the first semiconductor layer **404**, and then the second semiconductor layer **406** is formed on the light emitting layer **405**.

In the embodiment, the first semiconductor layer **404** and the second semiconductor layer **405** are an n-type epitaxial layer and a p-type epitaxial layer, respectively. However, the type of the first and the second semiconductor layers can be exchanged.

As shown in FIG. **4**B, a portion of the stacked epitaxial structure E are etched to the epitaxial substrate **403** to form a plurality of sidewalls of stacked epitaxial structure E and to expose a portion of the epitaxial substrate **403** (step S**302**). In this step, the sidewalls can be formed by a photolithography process and an etching process, such as photoresist coating, exposing, development, etching, photoresist removing, and so on. The etching process can be carried out by a dry etching or a wet etching. As shown in FIG. **4**C, after the etching process, an insulating protective layer **408** is formed on a portion of the second semiconductor layer **406** of the stacked epitaxial structure E, the sidewalls of the stacked epitaxial structure E, and the exposed epitaxial substrate **403** (step S**303**). The material of the insulating protective layer **408** is an insulating dielectric material such as oxide, nitride, or silicon carbide and so on.

Then, a plurality of electrodes **410** are formed on the epitaxial structure (step S**304**). The electrodes **410** are disposed on the second semiconductor layer **406** to form an LED device **40**. Because the electrodes are defined first in this step instead of forming the electrodes after adhering the structure to a temporary substrate, product yield is efficiently improved and manufacturing is simplified.

As shown in FIG. **4**D, after forming the electrodes **413**, a temporary substrate **409** is formed on the LED device **40** (step S**305**), and the temporary substrate **409** covers the electrodes **410**. The temporary substrate **409** can be directly formed by a curable polymer material such as glass, thick film photoresist, or fluorinated rubber and so on. When curable polymer material is used as the material of the temporary substrate **409**, the forming process of the temporary substrate **409** can include forming a curable polymer material on the light emitting diode device, and curing the curable polymer material. The curable polymer material can be formed on the light emitting diode device by spin coating, screen printing, or gel dispensing and so on. The curable polymer material can be cured by photo curing, thermal curing, or cool curing. In addition, the curable polymer material can be used as a bonding layer to bond a substrate, and thus the temporary substrate **409** is directly formed by the substrate and the curable polymer material.

As shown in FIG. **4**E, after forming the temporary substrate **409**, the epitaxial substrate **403** is removed to expose a bottom surface of the stacked epitaxial structure E and a portion of the insulating protective layer **408**, wherein the epitaxial substrate **403** can be removed by laser ablation, polishing, or etching and so on (step S**306**).

As shown in FIG. **4**F, after removing the epitaxial substrate **403**, a seed layer **401** is formed on the bottom surface of the stacked epitaxial structure E, wherein the seed layer **401** includes a reflective layer, an ohmic contact layer, and a metal bonding layer (step S**307**). The material of the reflective layer can be either a dielectric material or a metal. The metal can include Al, Ni, Ti, Pt, Au, Ag, Cr/Al, Ni/Al, Pd, Ti/Al, Ti/Ag, Cr/Pt/Au or any combination thereof. The material of the ohmic contact layer can include Ni/Au, ITO (indium tin oxide), IZO (indium zinc oxide), or AZO (aluminum doped zinc oxide). In another embodiment of the invention, the seed layer **401** can be formed of a single layer, i.e. an ohmic contact layer with a function of reflective metal layer. The material of the ohmic contact-reflective metal layer can include Al, Ni, Ti, Ge, Cr, Pt, Au, Ag, Ni/Cr, Cr/Au, Ni/Ag, Pd, Ti/Au, Ti/Ag, Cr/Pt/Au, Ti/Al/Ti/Au, Au/Ge/Ni, Ti/Pt/Au, Ti/Al/Pt/Au or any combination thereof.

A patterned photoresist layer **402** is formed on the seed layer **401** to expose a portion of the seed layer **401**, wherein the patterned photoresist layer **402** defines a plurality of confined areas CA with the seed layer **401** exposed (step S**308**).

Then, as shown in FIG. **4**G, at least a heat-conductive plate **407** is formed on the LED device **40** (step S**309**). The heat-conductive plate **407** can be formed on the seed layer **401** by electrochemical deposition, electric forging, or electroplating. The location of the heat-conductive plate **407** is defined by the confined areas CA of the patterned photoresist layer **402**. The material of the heat-conductive plate can include at least a heat-conductive metal such as Ni, Cu, Co, Au, or Al and so on. It should be appreciated that the heat-conductive plate **407** can be formed by a single material such as Au (as shown in FIG. **5**A) or Cu (as shown in FIG. **5**B) or a plurality of heat-conductive metals with multilayer structure such as Cu—Ni—Cu (a shown in FIG. **5**C) or Ni—Cu—Ni (as shown in FIG. **5**D) and so on. However, the material of the heat-conductive plate is not limited to the materials mentioned above, any material which can achieve good heat conductivity can be applied in the embodiment of the invention.

As shown in FIG. **4**H, the temporary substrate **409** is removed to form a plurality of vertical LED devices **4** (step S**310**). The temporary substrate **409** can be removed easily by laser ablation, polishing, etching, heating, or organic solvent due to the characteristics of the curable polymer material used such as its removability, expandability, and ductility. While the temporary substrate is removed, a portion of the insulating protective layer **408** and the seed layer **401** are also removed. Thus, the device separates automatically to form a plurality of LED devices **4**.

In the embodiment, the heat-conductive plate is formed on the first semiconductor layer **404**. Because the resistance of the n-type epitaxial layer (N—GaN) is lower, it is not necessary to use a transparent conductive layer in the structure of the seed layer **401** between the first semiconductor layer **404** and the heat-conductive plate **407** to achieve good current diffusion.

Moreover, because a dicing process to the heat-conductive plate **407** to obtain the LED devices in the embodiment of the invention is not required, the problem of leakage current generated from the dicing process can be prevented. In addition, the insulating protective layer **408** disposed on the sidewalls of the stacked epitaxial structure E also has an electric isolation function and can assist in reducing leakage current.

What should be noted here specially is that the steps are not limited to the sequence mentioned above. The sequence of each step can be exchanged according to manufacturing process requirements.

As described above, the manufacturing method for an LED device according to the embodiment of the invention uses a curable polymer material to directly form a temporary substrate on an LED device, and forms at least a heat-conductive plate on the LED device. Compared with prior art methods, the invention not only reduces the step of using a bonding layer to adhere the semiconductor structure to another substrate but also naturally separates the device into a plurality of LED devices after easily removing the temporary substrate due to the characteristics of the curable polymer material used such as its removability, expandability, ductility and so on. Thus, the problem of leakage current generated from the dicing process can be prevented. Further, the costs of the dicing process can be saved and product yield can be improved.

Moreover, the heat-conductive plate in the embodiment of the invention is formed by electroplating, electric forging, electroforming or electrochemical deposition and so on. Thus, the problems in the prior art such as low heat conductivity of the transparent bonding layer made of a plastic material or diffusion inside the LED device caused by the manufacturing process with high temperature and high pressure can be prevented, thus, improving the heat conductivity and the product yield. In addition, the heat-conductive plate of the invention has low residual stress and heat corrosion resistance which can prevent the separation between the stacked epitaxial structure and the heat-conductive plate or the damage of the stacked epitaxial structure, thus, increasing product yield and decreasing manufacturing costs. Moreover, the presence of the insulating protective layer can further reduce leakage current.

While the invention has been described by way of example and in terms of preferred embodiment, it is to be understood that the invention is not limited thereto. To the contrary, it is intended to cover various modifications and similar arrangements (as would be apparent to those skilled in the art). Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A method for manufacturing a light emitting diode device, comprising:

forming a stacked epitaxial structure on an epitaxial substrate;

removing a portion of the stacked epitaxial structure and a portion of the epitaxial substrate to form at least a hole extending into the epitaxial substrate, wherein the hole exposes a plurality of sidewalls of the stacked epitaxial structure and a portion of the epitaxial substrate;

forming an insulating protective layer on the sidewalls of the stacked epitaxial structure and the portion of the epitaxial substrate exposed;

forming at least a temporary substrate overlying the stacked epitaxial structure, the insulating protective layer, and the sidewalls of the stacked epitaxial structure for supporting the stacked epitaxial structure with the sidewalls;

removing the epitaxial substrate to expose a bottom surface of the stacked epitaxial structure and a portion of the insulating protective layer;

forming at least a heat-conductive plate beneath the stacked epitaxial structure; and

removing the temporary substrate to automatically separate the stacked epitaxial structure into a plurality of LED devices.

2. The method for manufacturing a light emitting diode device as claimed in claim **1**, wherein the heat-conductive plate is formed by electrochemical deposition, electric forging, or electroplating.

3. The method for manufacturing a light emitting diode device as claimed in claim **1**, wherein the temporary substrate comprises a curable polymer material, a glass, a thick film photoresist, or a fluorinated rubber.

4. The method for manufacturing a light emitting diode device as claimed in claim **1**, wherein the step of forming the temporary substrate comprises:

forming a curable polymer material; and

curing the curable polymer material.

5. The method for manufacturing a light emitting diode device as claimed in claim **1**, wherein the stacked epitaxial structure sequentially comprises a first semiconductor layer, a light emitting layer, and a second semiconductor layer on the epitaxial substrate, and the first semiconductor layer and the second semiconductor layer are an n-type epitaxial layer and a p-type epitaxial layer, respectively, or are a p-type epitaxial layer and an n-type epitaxial layer, respectively.

6. The method for manufacturing a light emitting diode device as claimed in claim **1**, wherein a material of the insulating protective layer is an insulating dielectric material, oxide, nitride, or silicon carbide.

7. The method for manufacturing a light emitting diode device as claimed in claim **1**, wherein after the forming of the insulating protective layer, the method further comprises:

forming a plurality of electrodes on the stacked epitaxial structure, wherein the temporary substrate covers the electrodes and the insulating protective layer; and

removing the epitaxial substrate to expose one side of the stacked epitaxial structure and a portion of the insulating protective layer.

8. The method for manufacturing a light emitting diode device as claimed in claim **1**, wherein the temporary substrate is removed by laser ablation, polishing, etching, heating, or organic solvent.

9. The method for manufacturing a light emitting diode device as claimed in claim **4**, wherein the curable polymer material is formed by spin-coating, screen printing, or gel dispensing, and cured by photo curing, thermal curing, or cool curing.

10. The method for manufacturing a light emitting diode device as claimed in claim **7**, wherein the epitaxial substrate is removed by laser ablation, polishing, or etching.

11. The method for manufacturing a light emitting diode device as claimed in claim **7**, wherein after the removing of the epitaxial substrate, the method further comprises:

forming a seed layer on the side of the stacked epitaxial structure and the portion of the insulating protective layer; and

forming a patterned photoresist layer on the seed layer, wherein the patterned photoresist layer defines a plurality of confined areas for allowing the heat-conductive plate to be formed thereon.

12. The method for manufacturing a light emitting diode device as claimed in claim **11**, wherein the seed layer comprises a reflective layer, an ohmic contact layer, and a metal bonding layer.

13. The method for manufacturing a light emitting diode device as claimed in claim **11**, wherein the seed layer is an ohmic contact layer with a function of a reflective metal layer.

14. The method for manufacturing a light emitting diode device as claimed in claim **12**, wherein the material of the reflective layer comprises Ti, Ni, Al, Pt, Au, Ag, Cr/Al, Ni/Al, Pd, Ti/Al, Ti/Ag, Cr/Pt/Au or any combination thereof, and the material of the ohmic contact layer comprises Ni/Au, ITO, IZO, or AZO.

15. The method for manufacturing a light emitting diode device as claimed in claim **13**, wherein the material of the seed layer comprises Al, Ni, Ti, Ge, Cr, Pt, Au, Ag, Ni/Cr, Cr/Au, Ni/Ag, Pd, Ti/Au, Ti/Ag, Cr/Pt/Au, Ti/Al/Ti/Au, Au/Ge/Ni, Ti/Pt/Au, Ti/Al/Pt/Au or any combination thereof.

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